# Experimental Characterization and Modeling of Helium Dispersion in a ¼-Scale Two-Car Residential Garage

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# BACKGROUND I

- Due to global warming concerns there is a significant effort to develop and deploy hydrogen-fueled automobiles.
- A large fraction of hydrogen-fueled automobiles are likely to be parked in existing residential garages.
- Unintended releases of hydrogen in residential garages are possible.
- Residential building codes do not currently provide guidance on garaging hydrogen-fueled automobiles.
- Existing recommendations based on gasoline-fueled automobiles are likely to be insufficient due to differences in physical properties between hydrocarbon fuels and hydrogen.
- There is insufficient technical understanding of mixing and combustion behaviors of hydrogen when released into partially enclosed spaces to allow code bodies and authorities having jurisdiction to make informed recommendations.

# BACKGROUND II

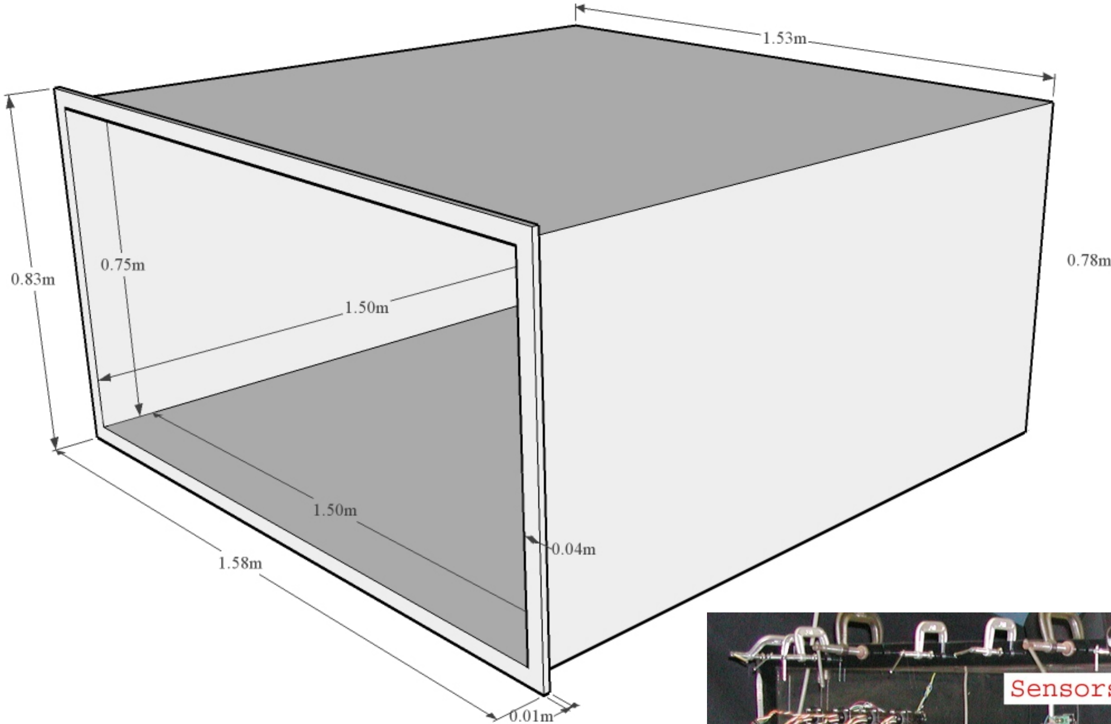
- Several studies have investigated releases of hydrogen (helium) into enclosed spaces. Most have focused on the distribution of the released gas within enclosures having limited ventilation.
- Studies have shown that residential garages are typically relatively leaky (3 to 10 ACH) with variable leak areas and locations.
- Building codes (ASHRAE and ICC) recommend residential garages have a minimum air exchange rate of 2.83 $m^3$/min (100 cfm) for each automobile housed, but the means for achieving this is not specified. This flow corresponds to 3 ACH for a standard sized garage. Note that a pressure of 4 Pa is often used as a representative pressure difference across the enclosure boundary.
- Computational fluid mechanics models should provide an approach for predicting hydrogen mixing in partially mixed spaces, but a recently published round robin study showed surprisingly large differences between predicted values and experimental findings.

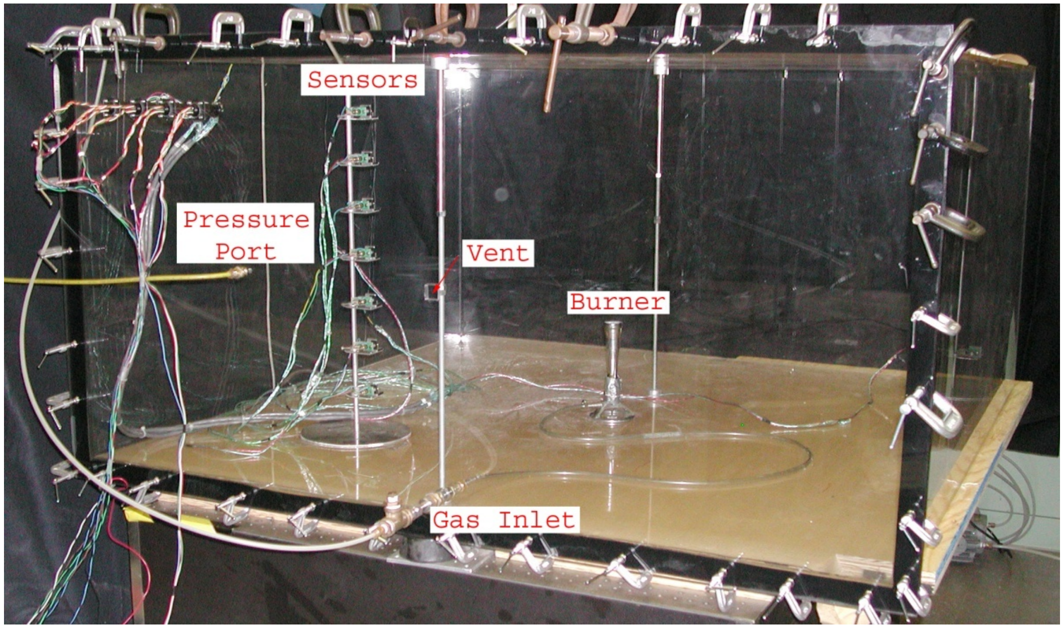
# CURRENT WORK

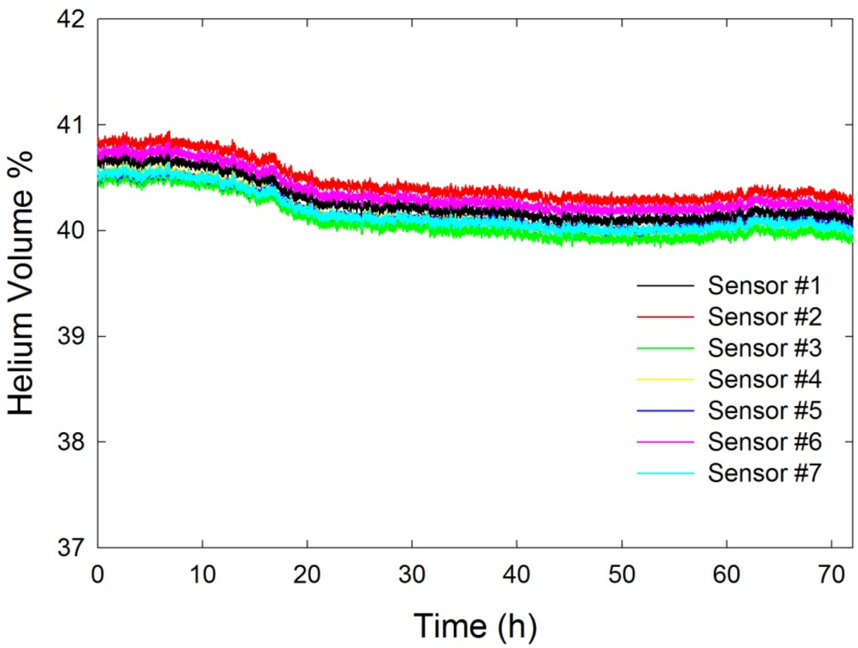
- NIST/BFRL is studying hydrogen (helium) dispersion and combustion following releases into partially enclosed spaces in order to provide technical guidance for the development of residential building codes for housing hydrogen-based technologies.
- Our initial effort has involved releasing helium into an idealized laboratory-scale enclosure geometrically scaled to represent a two-car garage with vents sized to provide roughly 3 ACH for a 4 Pa pressure differential. Vent(s) are placed in only one face.
- Little guidance was available for developing a hydrogen release scenario. We have assumed a steady release of 5 kg of hydrogen (full scale) over periods of one or four hours. Helium flow rates were scaled to match volume release rates on full scale.
- Experiments are designed to provide reference data for testing the NIST/BFRL CFD code FDS and to experimentally characterize effects of release time, release location, vent size, and vent location (s) on helium interior dispersion and exchange with enclosure surroundings.

# EXPERIMENTAL SYSTEM

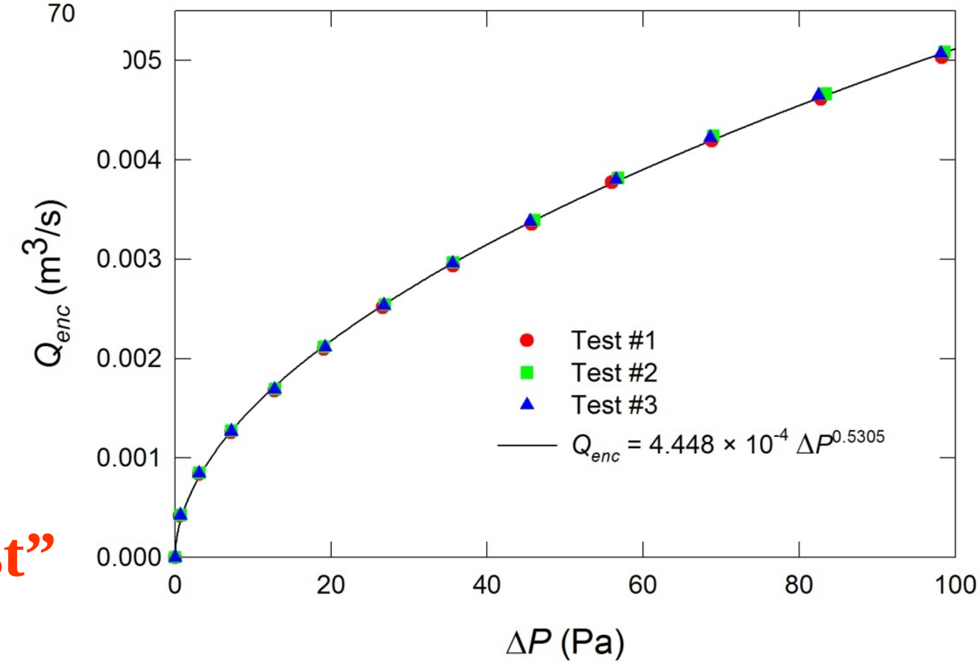
- Poly(methyl methacrylate) model scaled on a 6.096 m × 6.096 m × 3.048 m two-car garage has interior dimensions of 1.5 m × 1.5 m × 0.75 m (scale factor = 0.246).
- Helium released from Fischer burner with 3.6 cm diameter opening located 20.7 cm above base. A mass flow controller delivered volume flow rates of 14.8 L/min for one hour or 3.71 L/min for four hours.
- Helium volume fractions measured at seven heights (9.3 cm, 18.5 cm, 27.6 cm, 37.2 cm, 46.6 cm, 55.9 cm, 65.0 cm) along vertical line 37.5 cm from left side and front walls) using calibrated thermal conductivity sensors. An eighth sensor was used to check horizontal uniformity.
- Center face with single vents (2.40 cm square and 3.05 cm square) at the center and two vents (2.15 cm square) located 2.5 cm from the floor and ceiling.
- Helium released with burner on the floor at the center, on the floor at the rear (edge 3.0 cm from wall) and at the center 2.5 cm from ceiling.


1.53m
0.83m
0.75m
1.50m
0.78m
1.50m
0.04m
1.58m
0.01m


Sensors
Pressure Port
Vent
Burner
Gas Inlet




# Enclosure Sealed




# "Fan Pressurization Test"

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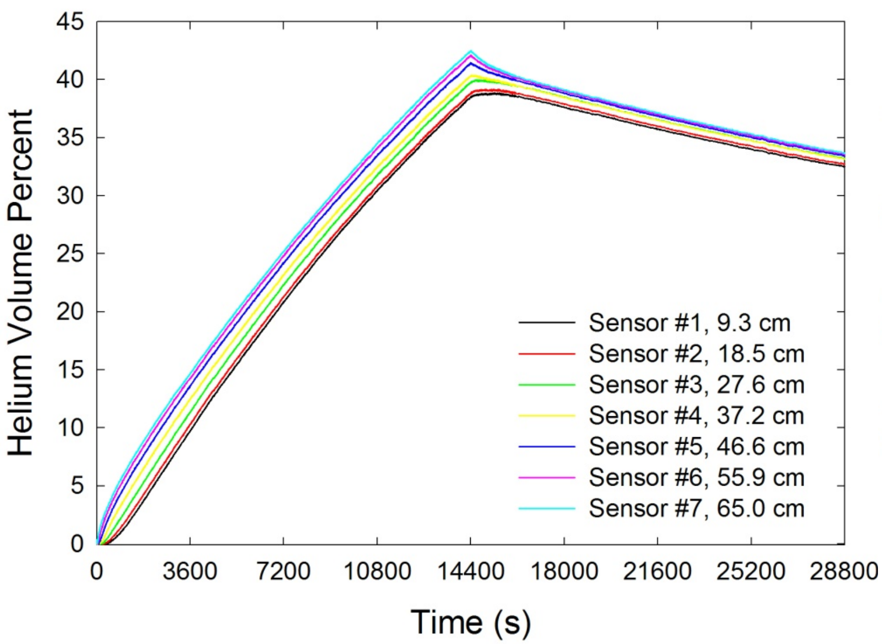
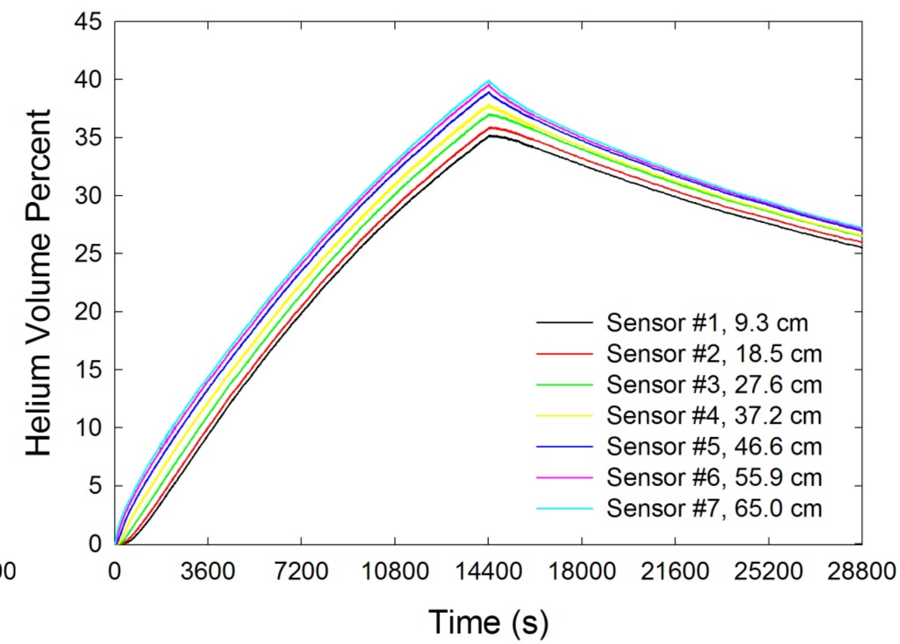
# Four Hour Releases
# Single Opening in Center of Face
# Release at Center Near Floor

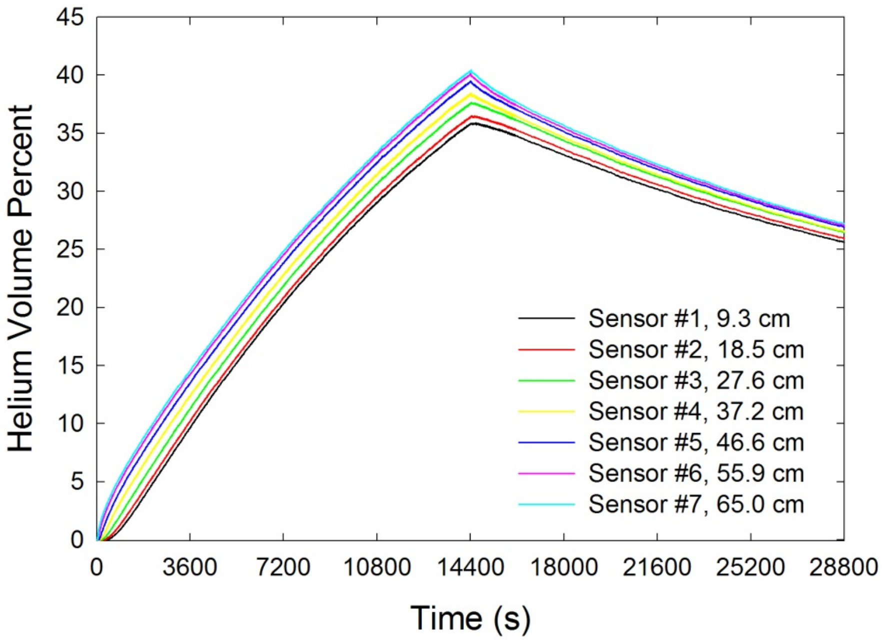



**2.40 cm square vent**

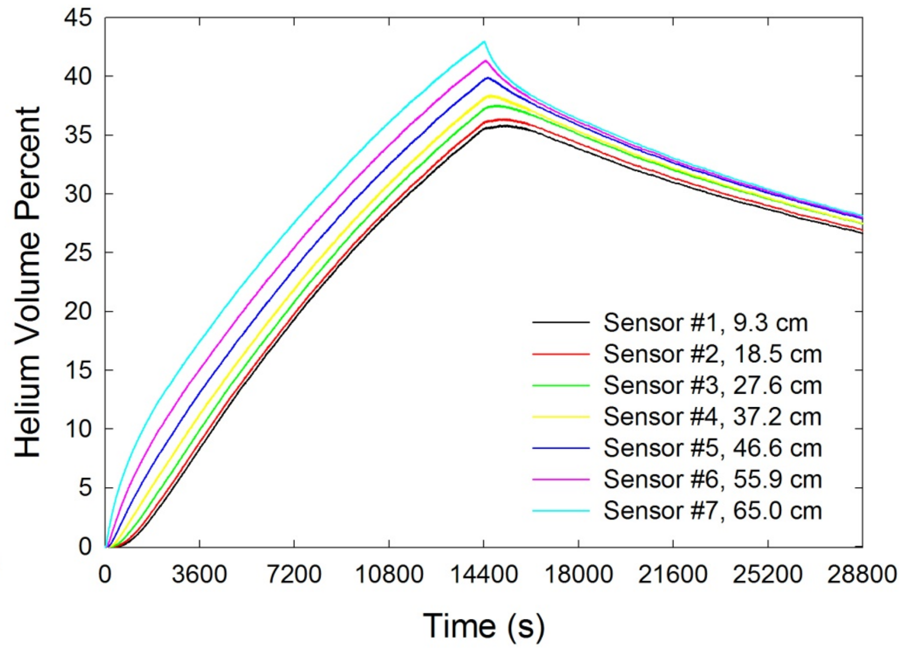



**3.15 cm square vent**

# Four Hour Releases
# Single Opening in Center of Face
# 3.05 cm Square Vent

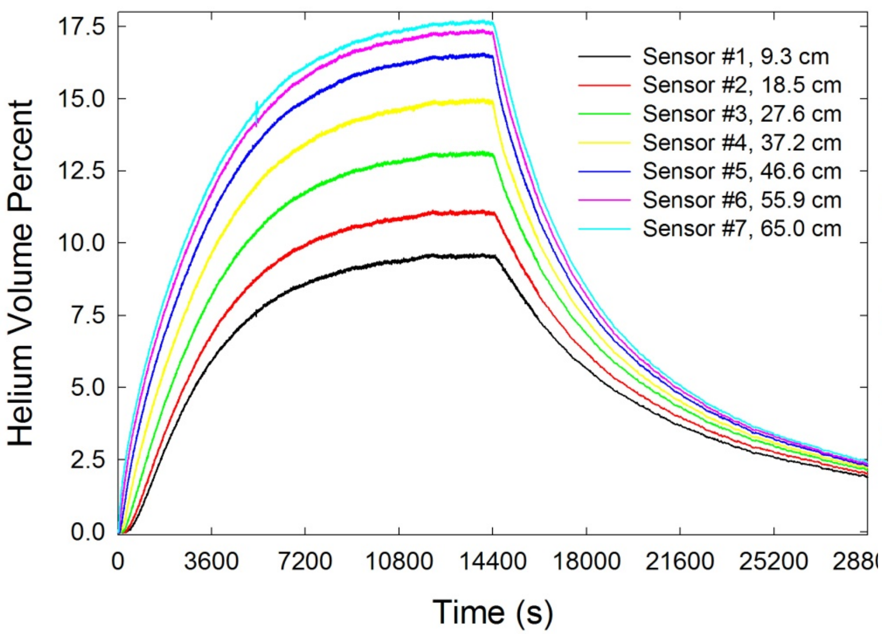



**Release at center near floor**

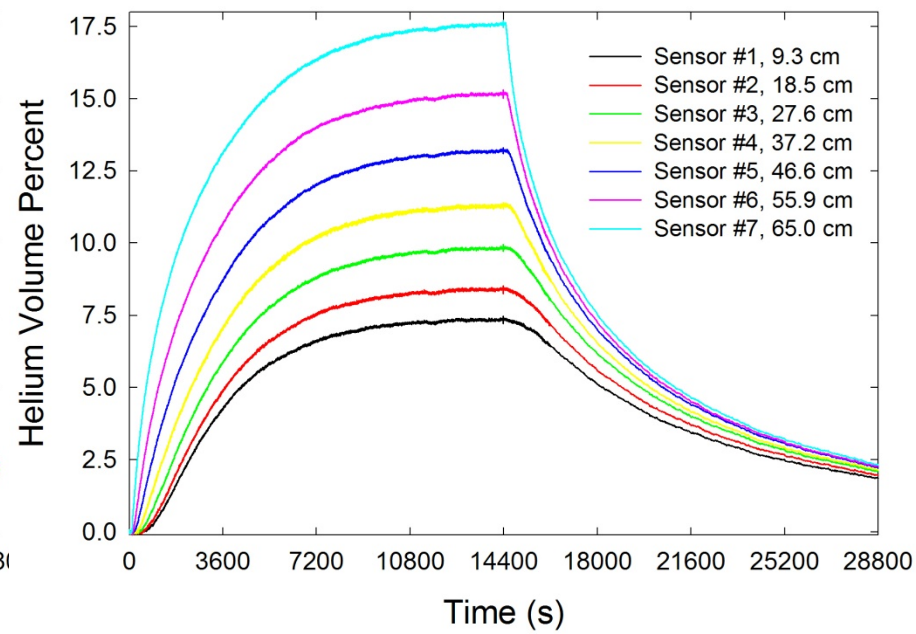



**Release at center near ceiling**

# Four Hour Releases
# Top and Bottom Openings in Face
# 2.15 cm Square Vents




**Release at center near floor**




**Release at center near ceiling**

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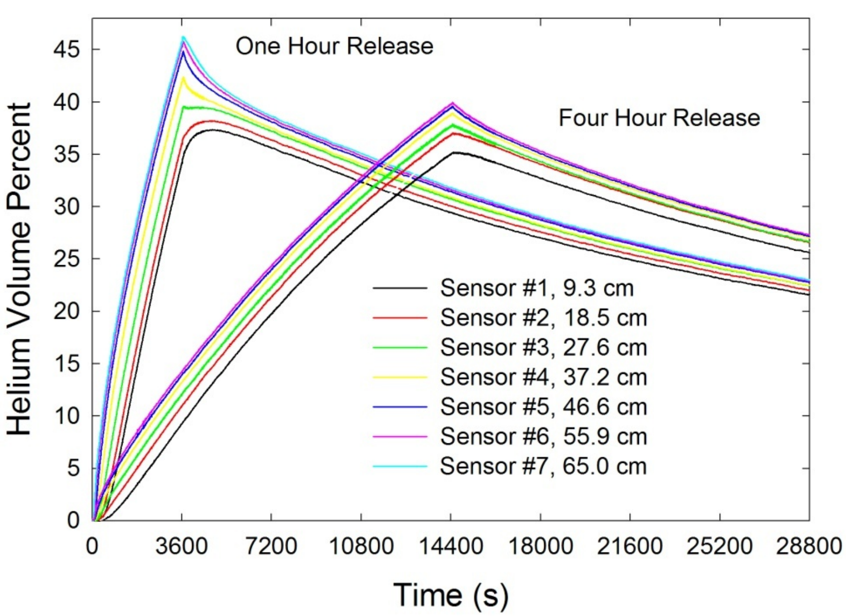
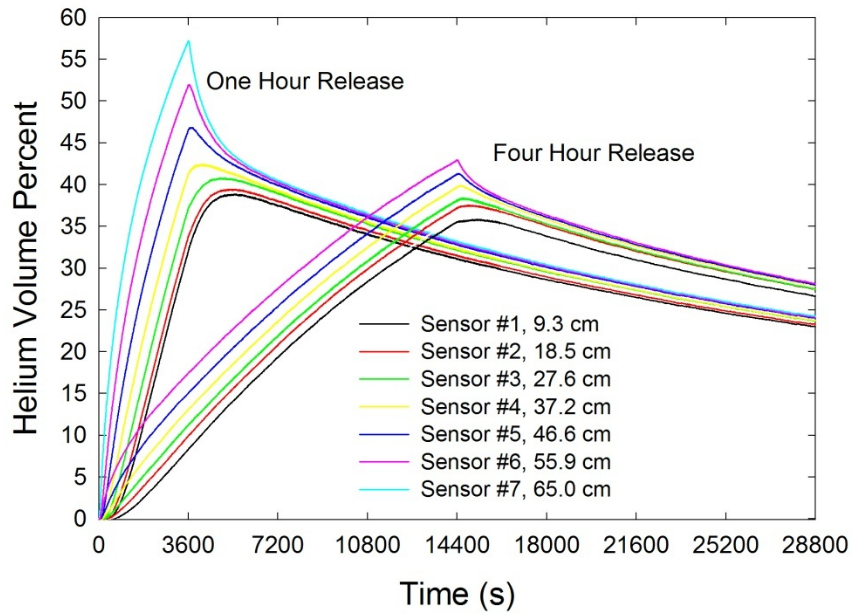
# One and Four Hour Releases Single Opening in Center of Face 3.05 cm Square Vent




**Release at center near floor** **Release at center near ceiling**

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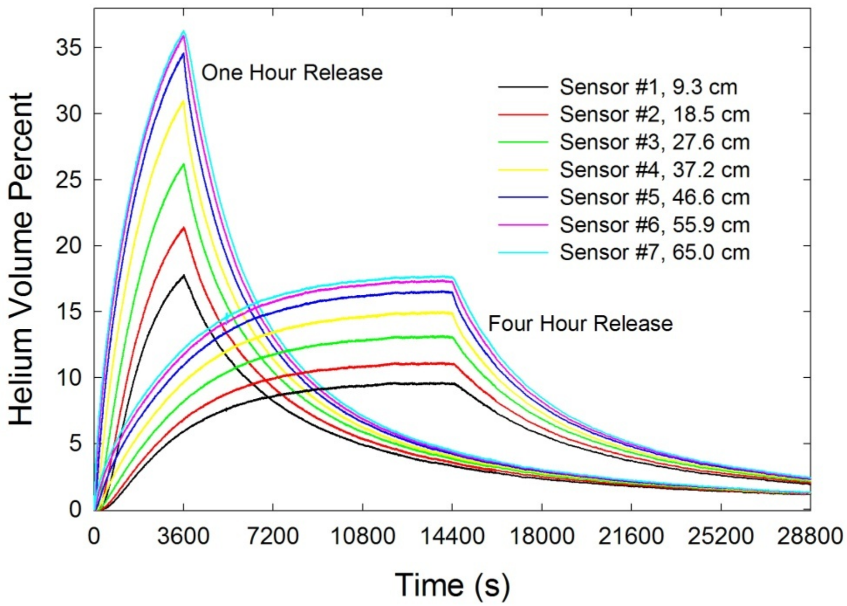
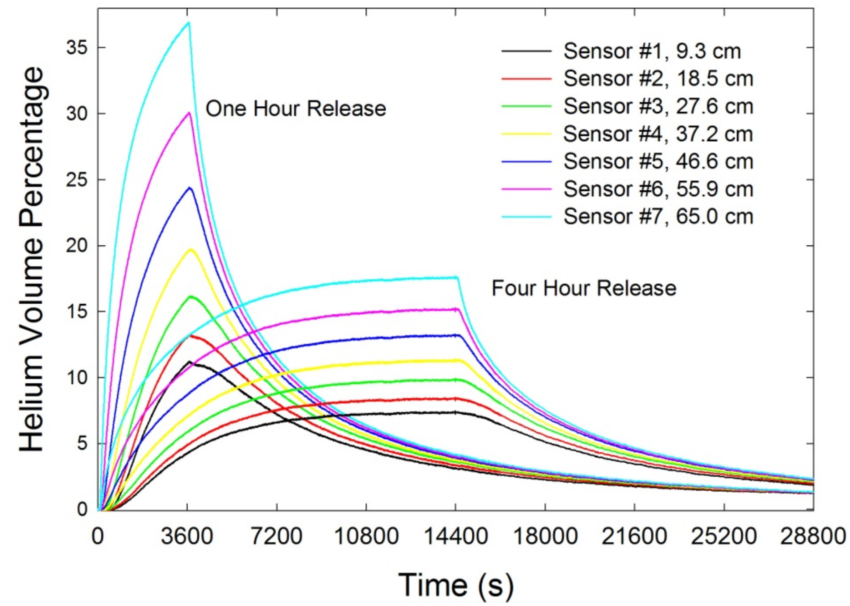
# One and Four Hour Releases Top and Bottom Openings in Face 2.15 cm Square Vents




Release at center near floor




Release at center near ceiling

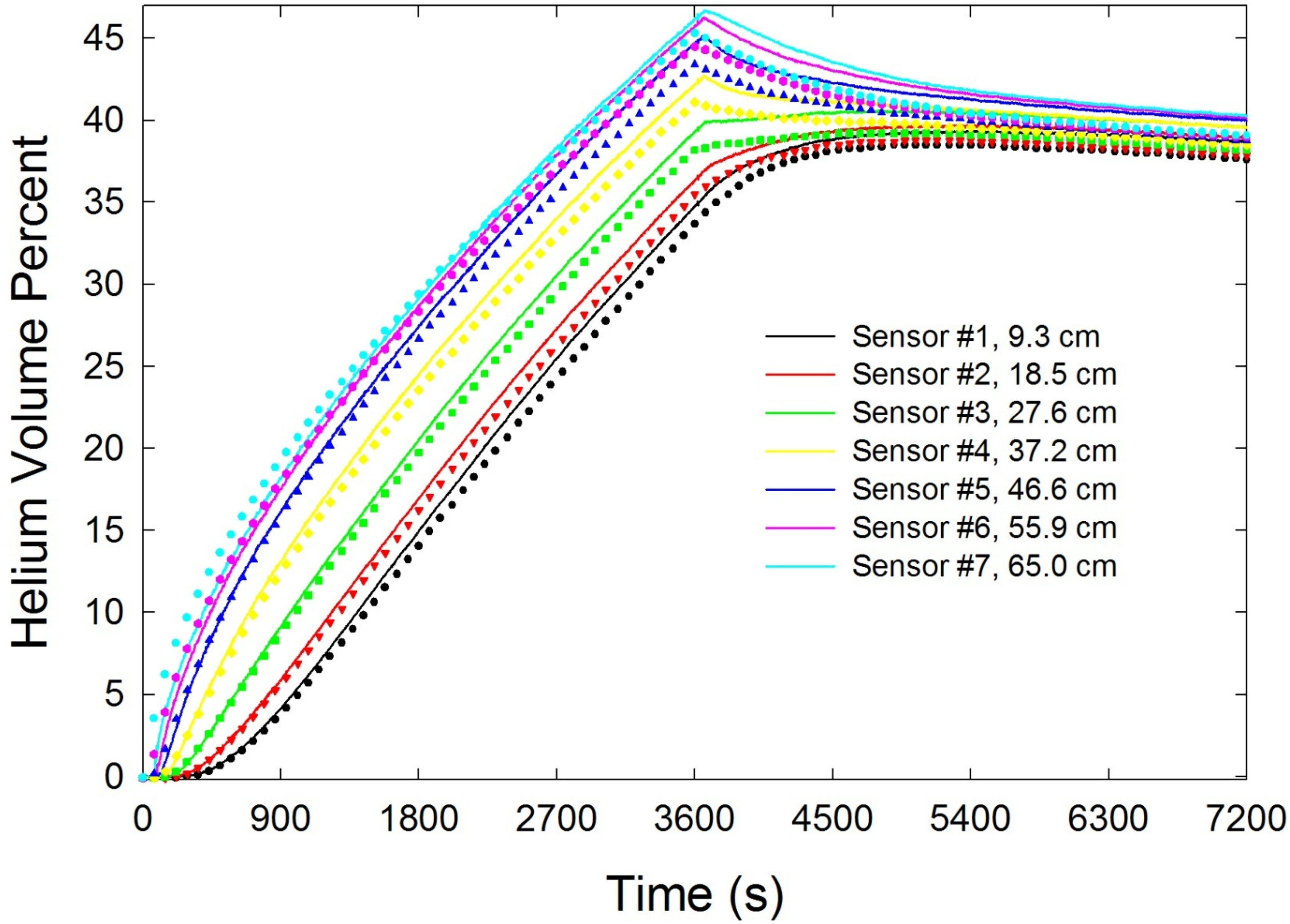
# SUMMARY OF EXPERIMENTAL OBSERVATIONS

- Helium volume fraction levels and distributions are strongly influenced by helium loss from the enclosure during release period.
- Relatively small differences in helium volume fraction levels and distributions were observed during the release period when the center vent area was increased by 60 %, but the fall off in helium volume fraction in the post-release period was noticeably higher.
- Two widely separated vertical vents with the same total area as the single vent in the face center results in lower helium volume fractions during the release and much faster fall off during the post-release.
- Releases near the floor varied little with position, but releases near the ceiling resulted in higher vertical concentration gradients and for single vents resulted in somewhat higher volume fractions near the ceiling.
- A shorter release period results in higher integrated helium volume fractions and stronger gradients within the enclosure.

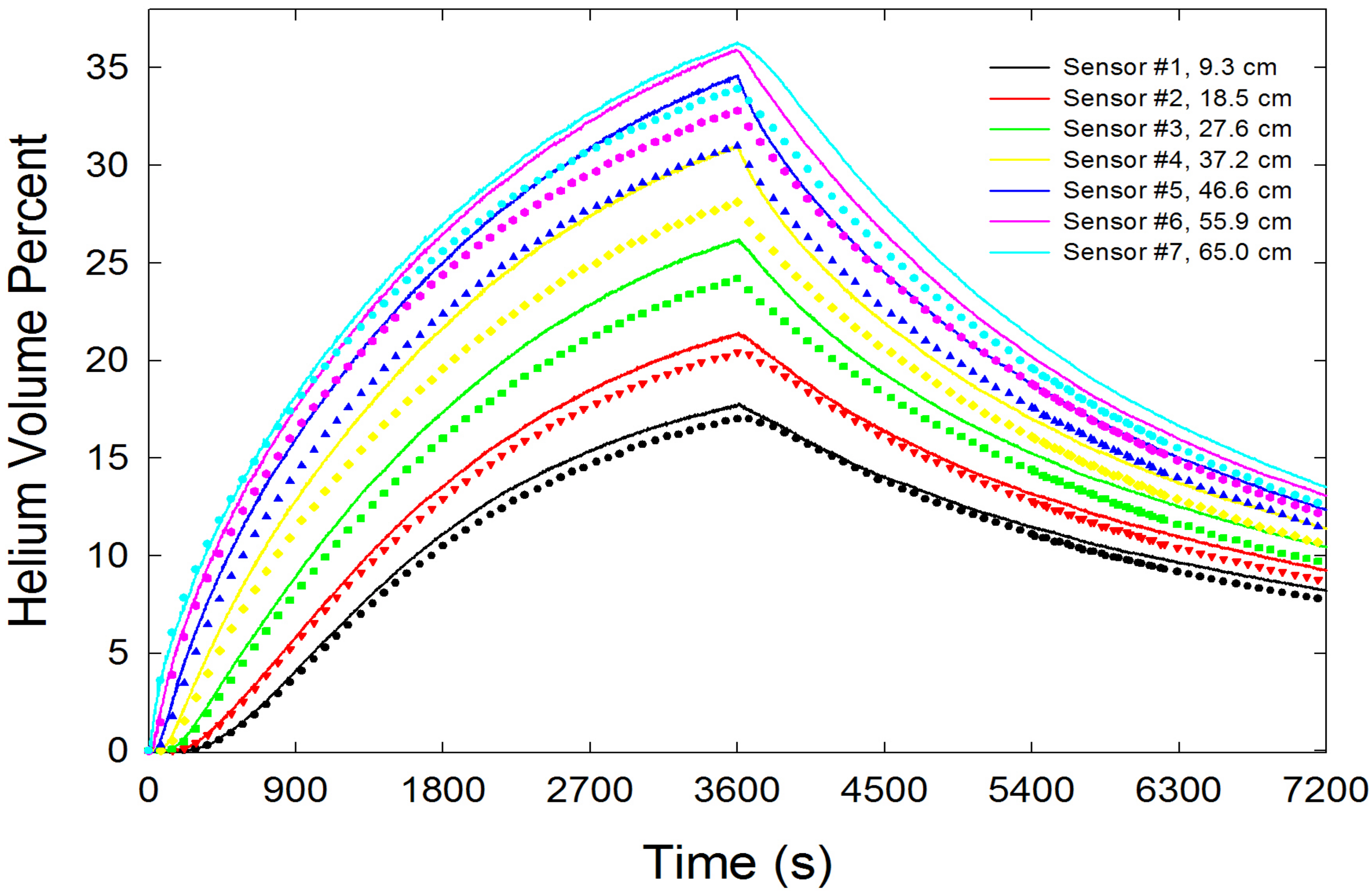
# FDS

- Large-eddy simulation (LES) based computational fluid mechanics (CFD) model.
- Developed for fire applications over several years, has been extensively tested and validated, used world wide by hundreds of fire researchers and fire protection engineers.
- Equations and algorithms are specially formulated to describe buoyancy induced flows.
- FDS was one of the CFD models included in round robin study based on INERIS experiments, also discussed in separate paper by Zhang et al. These studies showed relatively poor agreement with experiment that could be improved by adjusting the Smagorinski constant.
- Current experimental results have been modeled using FDS Version 5.2.0 with standard parameters.

# One Hour Release at the Center Near the Floor with Single 2.40 cm Square Opening in Front Face



# One Hour Release at the Center Near the Floor with Dual 2.15 cm Square Openings in Front Face



# FINAL COMMENTS

- Series of idealized experiments for release of helium into a ¼-scale two car garage have been described. Detailed results will be included in a NIST Internal Report. Additional experiments are on going.
- FDS has been shown to provide excellent predictions of experimental results in the ¼-scale facility.
- Further work is planned on releases of helium into the garage attached to NIST/BFRL Indoor Environment and Ventilation Test House.
- A series of experiments are underway (under contract) to study mixing and combustion behavior when hydrogen is released into a real-scale garage. Both an empty garage and a garage with automobile will be tested.

Indoor Environment and Ventilation Test House
NIST

Hydrogen Release Garage Test Facility
SWRI, San Antonio, TX